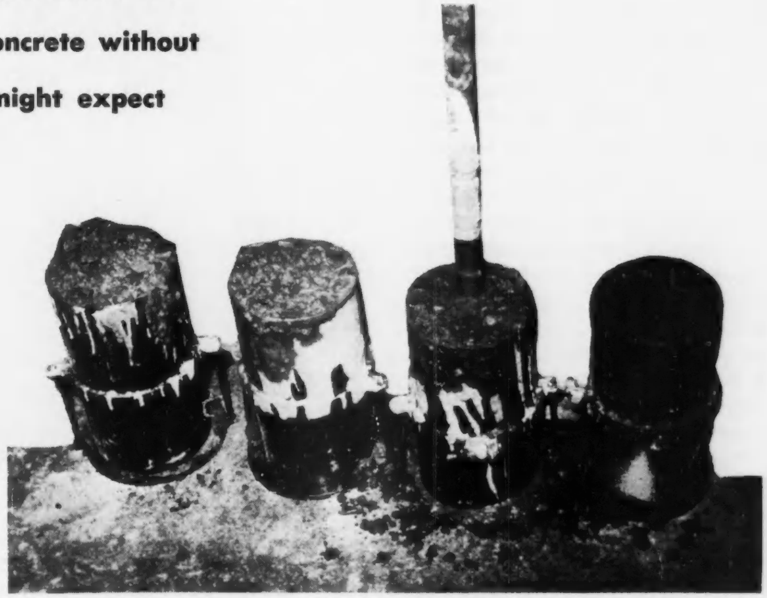
A New Look at Revibration

even when it's done long after initial set it improves the quality of concrete without any of the drawbacks you might expect



Concrete undergoing revibration in cylinder molds after a delay of five hours and fifteen minutes. Specimens were revibrated by inserting the vibrator for 4 to 40 seconds, at each of three locations, depending upon interval of delay.

CONCRETE MEN have long believed that it is dangerous to disturb the hardening of concrete once this process is definitely in progress. Although this opinion still prevails throughout the profession, there are a few dissenting views on the subject which may well form the nucleus of an entirely new school of thought.

The dissenters are experimenting with a relatively new technique called revibration. In the past revibration usually represented an emergency measure, adopted only when the completion of a pour was delayed for some reason. To prevent the formation of cold joints under such circumstances, many builders work the surface of the concrete, by tamping or vibrating, until the pour can be completed. Under favorable conditions initial set may be delayed in this fashion for several hours without any apparent harm to the finished structure.

But evidence is accumulating which indicates that revibration may be something more than just a desperation measure which happily has no ill effects on concrete. The new point of view is that this unorthodox practice can actually improve some of the important characteristics of hardened concrete. Among the major claims being made is that under properly controlled conditions revibration can increase density and strength, remove air and water pockets, release water trapped beneath horizontal reinforcing steel, improve bond between concrete and steel, and substantially reduce honeycombing.

Revibration as a beneficial technique was probably first applied successfully in the construction of concrete tankers and dry cargo ships during World War II. The shipbuilders found that leaks which showed up under hydrostatic pressure were generally the result of water being trapped under horizontal reinforcing steel. The subsequent evaporation of this water by heat of hydration left channels through which test fluids passed from one section of a ship's hull to another.

A number of remedial measures were tried, including the use of pressure grout impactors, but no real progress was made. Then someone suggested the unorthodox procedure of revibrating the concrete to force out the trapped water. The objection immediately arose that this rude disturbance of the hardening process would break initial bond, and very possibly foul up the crystalization of the cement. However, the problem was an urgent one, and the shipbuilders gave the go-ahead on a strictly experimental basis. The results were surprisingly successful. Not only was the immediate objective achieved without any of the anticipated drawbacks, but it was

found that the revibrated concrete was considerably stronger and formed a more tenacious bond with the reinforcing steel.

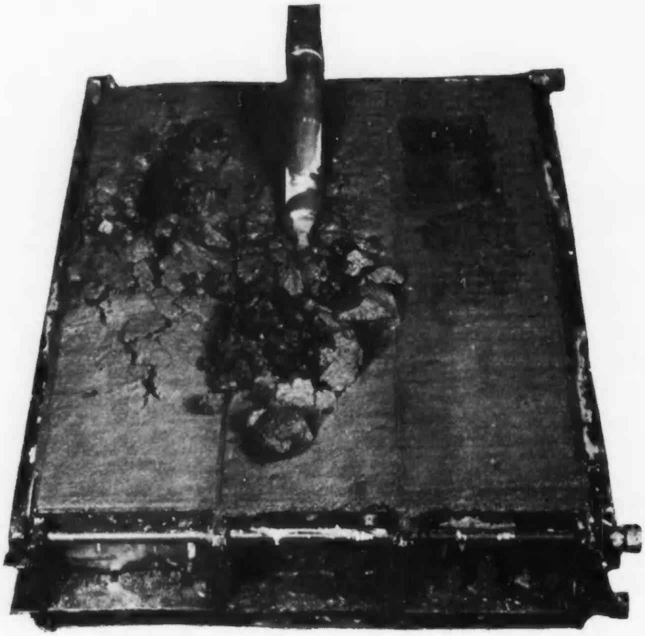
Since then equally impressive results have been obtained with revibration on certain dry dock and pier projects for which watertightness is a prime necessity. Here it was found desirable to use enough set retardant so that each course of concrete could be revibrated with the underlying course. This procedure prevented the formation of even the finest hairline cracks.

Revibration has also been used successfully to prevent the formation of cracks and cold joints in spandrel beams up to 12 feet in depth. By incorporating the proper amounts of retardants and making use of revibration, the entire mass of concrete in these beams was kept in a plastic condition for placement periods up to 7 hours. This made it possible to revibrate the entire depth of the beams after the completion of pouring operations.

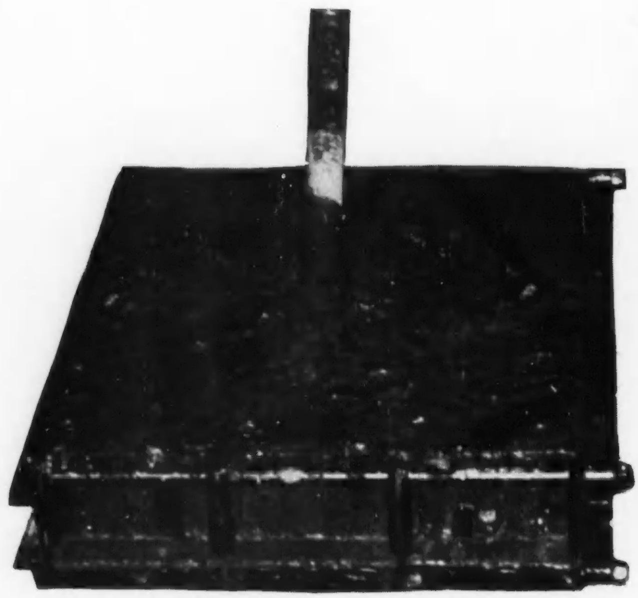
The Bureau of Reclamation has taken official notice of revibration in the sixth edition of its well-known *Concrete Manual,* which contains the following reference: "Revibration has been found to be beneficial rather than detrimental, provided that the concrete is again brought to a plastic condition. It may be accomplished by immersion-type vibrators, by form vibration, or by transmittal of vibration through the reinforcement system."

Strong support for the notion that revibration may be beneficial has resulted from a series of controlled experiments conducted by the research division of the Kentucky Department of Highways. At the 1956 annual meeting of the American Society for Testing Materials, D. H. Sawyer and S. F. Lee, respectively research engineer and resident engineer of the department, reported on the results of these experiments.

Their observations were made on a single 6-bag mix design, both with and without air extrainment. Samples of the two types were given normal vibration at the time of casting and then revibrated after various periods of delay. In the case of the non-air-entrained mix, revibration was found to be impractical when the interval of delay following the initial vibration was greater than 6 hours. The maximum permissible delay for the air-entrained mix was found to be 5¼ hours, the shorter interval apparently



Flexural specimens in a three-gang mold. The upper photograph shows the specimens being subjected to revibration after a 4-hour delay; the lower shows the same specimens immediately after the revibration.



resulting from the reduced water content of the mix.

The Kentucky tests indicate that revibration will increase the strength of concrete after any period of delay as long as the mix can be brought back to a plastic state. This appears to be true even if the vibrator must be forced into the concrete mixture. However, there are advantages to revibrating when the vibrator spud will just sink into the concrete of its own accord.

The accompanying graph shows that a maximum increase of about 36 per cent occurred in the compressive strength of 7-day specimens without air entrainment. This maximum strength increase occurred in specimens that were revibrated after a delay of approximately 4 hours. Increases of 24 and 15 per cent were found for the 24- and 90-day specimens. At each age test the air-entrained specimens showed about 50 per cent less strength increase than their non-air-entrained counterparts. The air-entrained specimens showed the maximum increase in strength when revibration was applied about 3 hours after casting.

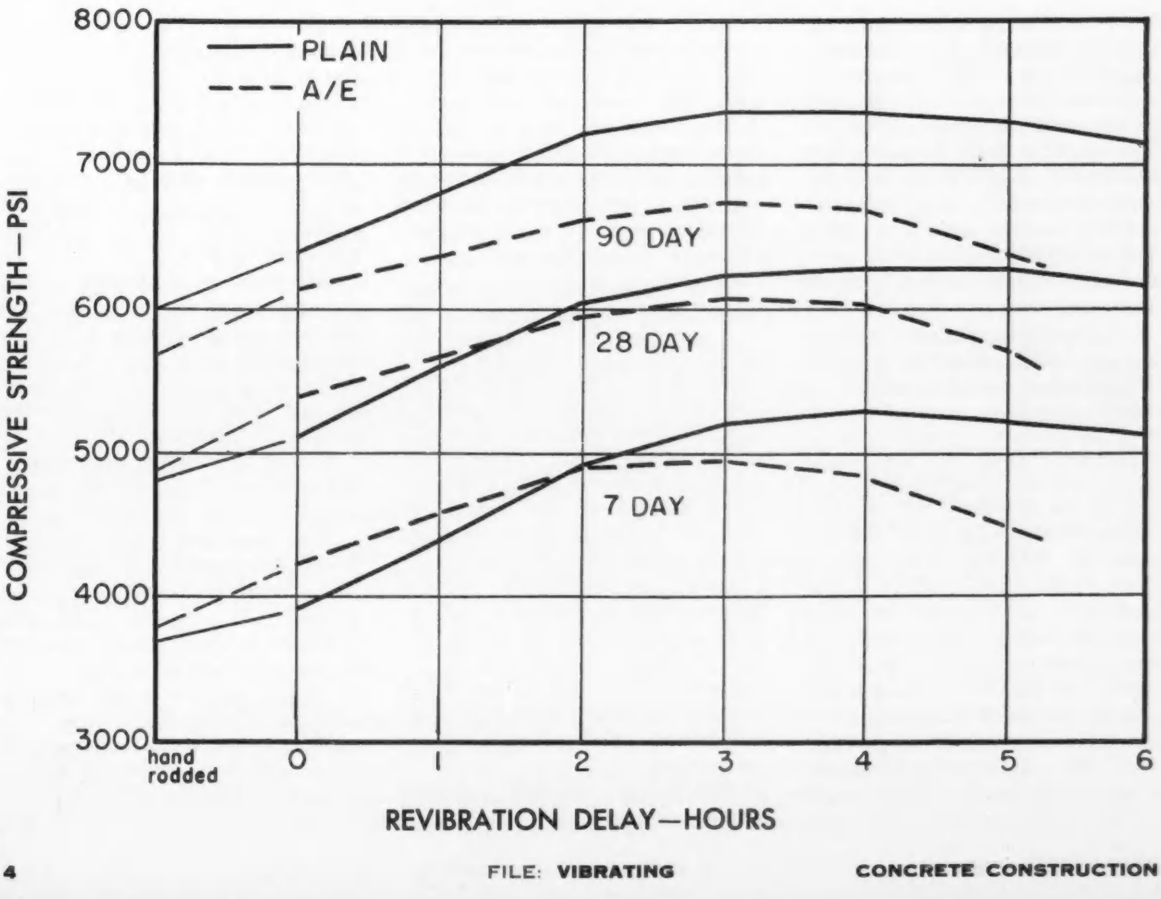
The Kentucky investigation seems to indicate that revibration not only speeds up the hardening process, but also causes a permanent increase in strength attributable to improved consolidation or other factors. A similar, but considerably smaller, gain was noted in the flexural strength of the revibrated specimens.

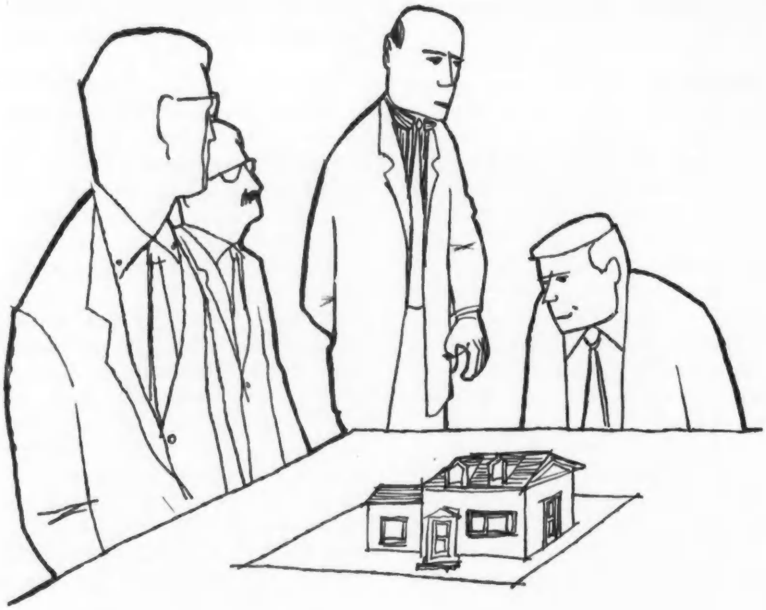
The Sawyer-Lee paper notes that in respect to durability, the advantages generally associated with air entrainment are most evident in revibrated concrete. In their tests they found that revibration results in a critical decrease in the durability of non-air-entrained concrete, whereas there is no significant loss in the case of air-entrained concrete. In non-air-entrained concrete revibration was found to effect an average decrease of 84 per cent in durability. This finding seems merely to reaffirm the importance of using air-entrained concrete whenever durability is an important consideration.

The Kentucky experimenters were not able to measure the effect of revibration on the permeability of concrete. Their work seems to justify the broad conclusion that this unorthodox treatment can have an important effect on strength as long as the concrete can be brought back to a plastic condition. They also concluded that there is little danger of overvibrating after any revibration delay, and that revibration is not likely to cause segregation. Still in progress are revibration studies involving a 4½-bag mix, and also mixes which contain set retardants.

Concrete men may not want to start revibrating on tomorrow's jobs, since much still remains to be learned about when, where, and how to employ this new technique for improving some of the characteristics of concrete. But at this writing there can be little doubt that it has challenging possibilities. CONCRETE CONSTRUCTION will make every effort to keep its readers informed of new developments in this promising field. END

Relationship between Compressive Strength and Revibration Delay for concrete with and without Air Entrainment





Changes by Building Research Advisory Board should mean . . .

Better Slabs for Less Money

SEVERAL CHANGES *have been made, and others are under consideration, which will have an important effect on the cost of slab-on-ground construction subject to FHA Minimum Property Requirements. For the most part, these changes fall into the cost-reduction column, but some others being studied by FHA might result in minor cost increases aimed at improving slab performance.*

Already written into new Minimum Property Requirements are three recommendations that seem bound to result in economies:

A ½-inch tolerance is now permitted in a 4-inch thick slab. This change will permit the use of 2-by-4 forms, and might reduce the slab concrete for a 1000-square foot house by as much as 1½ cubic yards.

Asphaltic coatings are no longer required to protect perimeter insulation against moisture. New MPR's merely require that perimeter insulation be "not permanently harmed by wetting or by contact with wet concrete mix." It is believed that this change could mean a savings of up to 8 cents per perimeter foot.

The new MPR's turn thumbs down on the use of waterproofing admixtures as a means of correcting deficiencies that can be prevented by sound construction practice. They approve, however, the use of air-entraining agents that result in improved durability, workability, and freezing resistance "at no extra cost."

Some other money-saving changes either under consideration or due for research study:

Omission of footings under interior bearing partitions when the loading is less than 500 pounds per linear foot.

The use of "limited capillarity" base materials in place of gravel or crushed stone. This provision will probably include a maximum limitation of 2 inches on the capillary rise of water.

Under some design conditions, vapor barriers might be omitted in favor of less costly separators to prevent wet concrete from penetrating the fill.

Under some design conditions and when certain floor coverings are used, a capillarity-breaking base might not be required.

Still in the discussion and study stage are several changes which might boost costs somewhat, but which would also result in better slabs:

The required use of wire mesh in all heated slabs, as well as in unheated slabs over 30 feet long. This requirement would be aimed at the elimination of serious shrinkage cracks. It could cost as much as $25 for a 1000-square-foot house.

Tops of slabs to be kept at least 8 inches above finished grades, and warm-air perimeter ducts at least 2 inches above grade.

The use of contraction joints where there is more than 10-foot offset in an L- or T-shaped slab.

Finished grading to be at least 4 per cent, compared with the present requirement of 2 per cent.

The required use of separators under heated slabs, or for any slab poured with concrete that tests over 4-inch slump.

All the foregoing changes and recommendations originated with a panel of experts assembled by the Building Research Advisory Board. This is an organization set up to coordinate and make widely available the building research conducted by private industry.

END

If you're interested in a new and simple field device

for measuring the consistency of plastic concrete . . .

Meet the Kelly Ball

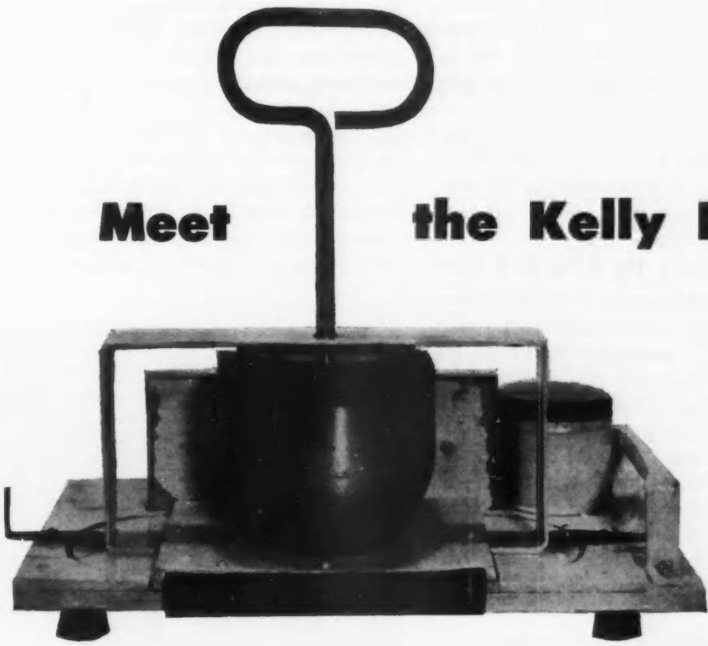


Photo by courtesy of Bureau of Public Roads.

A SIMPLE PENETRATION DEVICE for measuring the consistency of fresh concrete was recently announced by two men working in the Engineering Materials Laboratory of the University of California at Berkeley. The device is a portable metal ball, named the Kelly ball after one of these men, that penetrates the surface of concrete. Tests made with the Kelly ball at the University of California and elsewhere show results that compare favorably with results obtained through the more commonly known and used slump test. The results were so close that the Kelly ball was given a tentative standard rating by the American Society for Testing Materials.

For years, the slump test has been considered the best means of measuring the consistency of fresh concrete, particularly in the laboratory. Yet it has always left much to be desired when done at the job site, from the viewpoints of accuracy and ease and convenience of making the test. It requires time and close attention to get even reasonably good results. It was this dissatisfaction with the slump method that brought the convenient and time-saving Kelly ball into existence.

Construction of the Kelly Ball

Penetration devices for measuring concrete consistency are neither new nor are they unique to the United States. Other countries have used weights or plungers of different types for this purpose before. In devising the Kelly ball, therefore, it was recognized that lowering an object in fresh concrete was a possible means of measuring its consistency. The questions were: what size? what shape? what weight?

The tests conducted at the University of California Laboratory showed that a 6-inch metal ball carrying a weight of 30 pounds was the smallest and lightest object that would successfully penetrate the stiffest mixture of concrete, as well as overcome the resistence of large aggregates. For measuring very light-weight concrete, a 6-inch ball carrying a 20-pound weight was found to be adequate. The Kelly ball device can be used even in mass concrete containing aggregates as big as 6 inches if the penetration is carefully made only in areas free of these larger stones.

The Kelly ball, pictured in use on the opposite page, is made up of a steel handle, a vertical rod marked in inches and half inches with the inches numbered, a metal ball 6 inches in diameter and $4\frac{5}{8}$ inches in height, and a stirrup or frame into which the ball is set. The semi-circular bearing plates at each foot of the frame were added by the Bureau of Public Roads as an improvement over the original Kelly ball design. They serve to prevent the frame from tilting. This change has been incorporated in the Kelly ball that was given a tentative standard rating by the American Society for Testing Materials.

Another addition to the original Kelly ball is a movable pinch clamp to make it easier to measure depth of penetration. This clamp is attached to the top of the handle where it remains until the ball has penetrated the concrete. Then the clamp is lowered until it comes in contact with the frame. When the entire apparatus is removed from the concrete, the position of the clamp on the handle gives the depth of penetration of the ball. *(A detailed sketch of the Kelly ball, as modified by the Bureau of Roads and showing exact measurements, will be supplied free of charge on request. Write the Editor, Concrete Construction Magazine, 139 N. Clark, Chicago, Ill.)*

A special field kit can be constructed or purchased from an equipment dealer for conveniently carrying the Kelly ball to the job site. This is shown in the photo at the beginning of the article. It consists of a simple wooden base on which the Kelly ball apparatus is mounted. A tin can is added to hold rags for wiping the ball clean after each test. The wooden base serves a double duty. Besides carrying the apparatus, it can be used as a footboard for the person testing the wet concrete.

How to Make the Kelly Ball Test

The big advantage of the Kelly ball test is that it can be made quickly and easily at the job site, either directly in the fresh concrete or in a separate container. When the first course is followed, make the penetration at least 9 inches away from the face of any forms, piers, or walls. In pavement work, too, keep a horizontal distance of 9 inches between the penetration point on the subgrade and the form edge of the finished level section of concrete.

The depth of concrete to be tested for consistency should be at least 6 inches where maximum aggregate size is 2 inches. Where aggregates are larger, the minumum depth should be three times the size of the largest aggregates used.

The surface of concrete to be tested for consistency should be smooth and level. Try to keep the disturbance of the concrete caused by the ball limited to as small an area as possible.

Hold the ball vertically by the handle and bring it in light contact with the concrete surface. The zero mark on the rod should appear at the level of the frame. Then release the handle and let the ball sink into the concrete. The depth of the penetration will be indicated in inches on the rod which has slipped up through the frame from the zero mark. It isn't necessary to make any adjustment for the slight sinking of the bearing plates into the concrete. The photo on this page shows the Kelly ball test in action. At least three separate measurements of this kind should be carried out for each batch—each test to be made with the foot of the frame at least 6 inches from the place where it rested in the previous test. Since each test can be carried out in about a half a minute's time, there is no delay in the finishing operation.

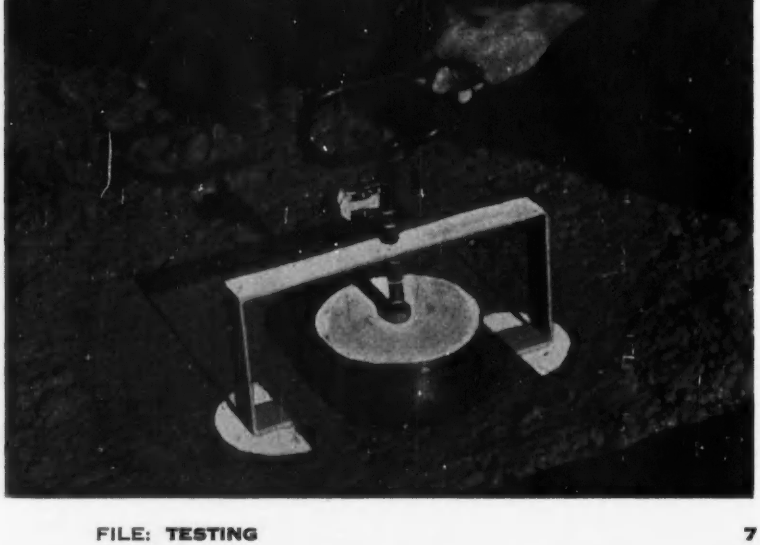
Advantages of the Kelly Ball Test

The chief advantage of the Kelly ball test is that it can be made at the job site, thus eliminating the time and effort required to make samples and ship them off to the laboratory. Three or more Kelly ball tests can be made in less time than it takes to make one slump test, thereby eliminating any delay in finishing operations. The Kelly ball is easy to carry to the job site and can be maintained simply by cleaning with an oily rag. The Kelly ball can be used to measure the consistency of concrete containing large coarse aggregate, as long as proper depth is allowed for penetration. Finally, since the Kelly ball does make it possible to measure the consistency of concrete quickly and easily, it will probably result in finer performance of concrete through wider use of testing.

Many organizations have adopted the ball test already, such as the Bureau of Public Roads; the state highway departments of California, North Carolina, and Colorado; and the Waterways Experiment Station, Concrete Division, U. S. Army Corps of Engineers. Maybe it's time for concrete contractors to "meet the Kelly ball." END

Above: The slump test—clumsy to handle and often inaccurate when made on the job site. Is it on the way out? Below: The Kelly ball in action. Notice that the concrete surface being tested is smooth and level.

Photo by courtesy of Bureau of Public Roads.



This article tells you when to expect trouble with plastic cracking and how to go about heading it off.

Plastic Cracking Can Be Prevented

CONCRETE CONTRACTORS who have occasional trouble with the formation of plastic cracks will be interested to know that this difficulty can be virtually eliminated. Plastic cracking is generally caused when a change in weather conditions brings about an increase in the rate at which water is evaporated from the fresh concrete surface. Such cracks usually appear when wind velocity, relative humidity, high air temperature, or a combination of all three, cause water to evaporate from the concrete surface faster than it is replaced by bleeding.

The accompanying tables are the result of extensive field investigations that show how various weather factors influence the rate of evaporation. For example, Table 1 indicates that when wind velocity increases from zero to 25 miles per hour, the rate of evaporation (in pounds of water per square foot per hour) is nine times greater.

Table 2 shows that when relative humidity decreases from 90 per cent to 10 per cent, the drying tendency is again almost nine times greater, while Table 3 shows that evaporation rate more than quadruples when both concrete and air temperatures increase from 50 to 90 degrees F. Tables 4 to 8 cover other fairly common conditions of temperature, relative humidity, and wind.

The tables merely provide a mathematical way of showing that the rate of evaporation is highest under the following conditions:

When the wind is blowing over the surface of the concrete.

When relative humidity is low.

When the temperature of the concrete is higher than the temperature of the air.

When both concrete and air temperatures are low.

While plastic cracking is perhaps most frequently encountered in summer concreting, when strong winds often occur in combination with high air temperatures and low humidities, it may also be experienced during cold weather operations. For example, the possibility is almost always present whenever the concrete temperature is high compared to the air temperature at the time of pouring.

Since the likelihood of plastic cracking is greatest whenever the rate of evaporation exceeds the rate at which water bleeds or rises to the surface of concrete, there are consequently two means of controlling the problem: by reducing the rate of evaporation and/or increasing the rate of bleeding.

The following procedures will tend to reduce the rate of evaporation:

Erecting windbreaks that reduce wind velocity over the surface of the concrete.

Shading the surface of the concrete from the rays of the sun.

Cooling the concrete in hot weather, and avoiding overheating it in cold weather.

Applying protective coverings, such as sand, wet burlap, paper or membrane curing compounds, as soon as possible. Use temporary coverings if there is to be a substantial delay between placing and finishing.

These job practices call for the cooperation of the ready-mix supplier and will reduce the danger of plastic cracking by increasing the rate of bleeding:

Avoiding when possible the use of excessively high cement contents and mixes that incorporate large amounts of fine aggregate.

Holding the water content of the concrete as high as possible, consistent with good design practice.

Dampening aggregates if they are dry and absorptive.

Dampening subgrades and forms before beginning pouring operations. END

Effect of Variations in Concrete and Air Temperatures, Relative Humidity, and Wind Speed on Drying Tendency of Air at Job Site

Variables	Case No.	Concrete Temp °F	Air Temp °F	Relative Humidity, %	Dew Point, °F	Wind Speed	Drying Tendency lb./sq.ft./hr.
1.—Increase in Wind Speed	1	70	70	70	59	0	.015
	2	70	70	70	59	5	.038
	3	70	70	70	59	10	.062
	4	70	70	70	59	15	.085
	5	70	70	70	59	20	.110
	6	70	70	70	59	25	.135
2.—Decrease in Relative Humidity	7	70	70	90	67	10	.020
	8	70	70	70	59	10	.062
	9	70	70	50	50	10	.100
	10	70	70	30	37	10	.135
	11	70	70	10	13	10	.175
3.—Increase in Concrete and Air Temperatures	12	50	50	70	41	10	.026
	13	60	60	70	50	10	.043
	14	70	70	70	59	10	.062
	15	80	80	70	70	10	.077
	16	90	90	70	79	10	.110
	17	100	100	70	88	10	.180
4.—Concrete at 70° F; Decrease in Air Temperature	18	70	80	70	70	10	.000
	19	70	70	70	59	10	.062
	20	70	50	70	41	10	.125
	21	70	30	70	21	10	.165
5.—Concrete at High Temperature; Air at 40° F and 100% R. H.	22	80	40	100	40	10	.205
	23	70	40	100	40	10	.130
	24	60	40	100	40	10	.075
6.—Concrete at High Temperature; Air at 40° F; Variable Wind	25	70	40	50	23	0	.035
	26	70	40	50	23	10	.162
	27	70	40	50	23	25	.357
7.—Decrease in Concrete Temperature; Air at 70° F	28	80	70	50	50	10	.175
	29	70	70	50	50	10	.100
	30	60	70	50	50	10	.045
8.—Concrete and Air at High Temperature 10% R. H.; Variable Wind	31	90	90	10	26	0	.070
	32	90	90	10	26	10	.336
	33	90	90	10	26	25	.740

The use of good-quality rubber sheeting now makes it easy to produce . . .

New Patterns in Concrete Surfaces

Imparting a pattern to the finished surface of concrete is becoming more widely recognized as having a practical as well as a decorative value. In precasting work, the patterns serve to show the builder which units belong together. Moreover, figured surfaces seem to show less tendency to craze than do smooth surfaces.

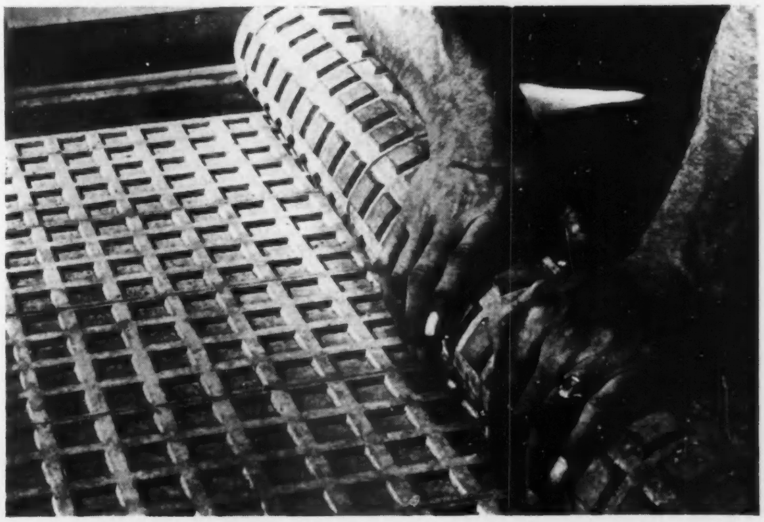
BY CASTING CONCRETE against ordinary rubber sheeting, it is now reported possible to virtually "peel off" a striking pattern on finished concrete. This new and simple technique depends for its success on the pliability of the rubber as opposed to the rigid materials usually employed to produce a figured surface.

The process is the result of experiments made by Prestressed Concrete Ltd., of Great Britain, and although it is still in the developmental stage it is well worth the consideration of concrete builders in this country.

Rubber sheeting of the desired pattern is placed on the bottom of the form or casting frame. Concrete of the same proportions as would be used for any precasting is then poured into the mold, vibrated, and allowed to set. After it has set, the frame is removed and the unit turned upside down. The rubber sheeting, now on top, is then peeled away from the concrete surface, leaving a bold and striking imprint such as the accompanying photos illustrate.

The quality of the rubber is, understandably, an important element in the success of this technique. Thick, strong sheeting will not tear as it is pulled from the concrete surface. Good-quality rubber is an economical material, too, for it can be stored and re-used if the proper precautions are taken. It must be kept clean—with all concrete dust removed—and stored in a cool place away from sunlight.

The British manufacturers report a wide variety of patterns currently in use. However, the best results in concrete seem to be achieved through simple, bold surface patterns that are easily visible. END



Each of the five principal types of cement has pretty definite job applications. Here is what you should know about . . .

Types of Portland Cement

GENERALLY SPEAKING, users of concrete for ordinary construction purposes have little need to become involved in portland cement specifications. But any concrete builder or technician worth his salt should know something about the various types of portland cement that are available, and have some knowledge of the purposes for which each is used.

Type I cement is made for use in general concrete construction. It should be regarded as a standard material to be used on all work where no unusual conditions or requirements are likely to be encountered. Ready-mixed concrete is usually batched with Type I cement unless some other type is specified by the purchaser.

Type II cement imparts to concrete all the essential characteristics obtainable with Type I cement, plus improved resistance to sulfate attack, less generation of heat, somewhat better workability, lower permeability, and less tendency to bleed. Type II cement is ground somewhat finer than Type I, and it has a somewhat different chemical composition. Concrete made with Type II cement will show lower early strength than concrete containing Type I cement, but at three months there is no important difference in strengths. (See table)

Type III cement is often referred to as high-early-strength cement. It is ground much finer than Types I and II and its most important characteristic is rapid development of strength. It is used in emergency construction, or under any conditions that require early discontinuation of curing and protection. As the table indicates, the strength advantage of concrete made with Type III cement drops steadily with age, eventually equaling that of concretes made with Types I and II cement. High-early strength can also be obtained at somewhat less cost by using an accelerator with either Type I or Type II cement.

Type IV cement generates less total heat, and does it at a slower rate, than the other types. It is used mainly in massive concrete structures to prevent the severe cracking that may occur when high temperatures are reached during hydration. Concrete made with Type IV cement is not generally suitable for ordinary structures because it requires extra care at early ages, and prolonged curing (21 days or more) is necessary to obtain adequate strength and weather resistance. As the accompanying table shows, Type IV cement develops compressive strength rather slowly, but with adequate protection and curing it reaches equality with concrete made with Type I cement.

Type V cement provides the highest attainable resistance to alkali attack, and for this reason it is generally specified for structures which come in contact with water or soil having large concentrations of sulfates. Early strengths are low, but are somewhat higher than for Type IV cement. It also compares favorably with Type IV cement in respect to heat generation. When proper curing conditions are maintained, concrete made with Type V cement attains excellent strength.

Air-entraining cements, though not a new type, are sometimes used to produce air-entrained concrete. This kind of cement contains a small amount of an air-entraining agent interground with the clinker. Types I, II, and III cements may contain such additions, and for purposes of identification they are then referred to as IA, IIA, and IIIA. Air entrainment can usually be somewhat better controlled when the air-entraining agent is added at the mixer, and for this reason there has been in recent years a noticeable drift away from air-entraining cements.

To summarize, Type I cement will provide excellently for most of the conditions normally met in concrete construction. Type II is also an excellent all-purpose material, but in addition provides moderate alkali resistance and less heat of hydration. Type III is used where rapid strength development is necessary, and Type IV where low heat generation is a major consideration. Type V is used whenever sulfate conditions are expected.

When sulfate conditions are anticipated, the soils and/or waters involved should be analyzed. The use of Type II cement is usually indicated when the SO_4 content of water exceeds 150 parts per million, or when the percentage of water-soluble SO_4 in air-dry soil exceeds 0.1 of 1 per cent. Type V cement is indicated when these values reach 1000 parts per million and 0.2 of 1 per cent, respectively. END

Relative Strengths of Concretes Made with Various Types of Portland Cements

Type of Cement	COMPRESSIVE STRENGTH—Percentage of Strength of Type I Concrete		
	3 Days	28 Days	3 Months
I	100%	100%	100%
II	80%	85%	100%
III	190%	130%	115%
IV	50%	65%	90%
V	65%	65%	85%

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